CHAPTER 5: EFFECTIVENESS OF BEST MANAGEMENT PRACTICES

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SUMMARY

Runoff from the Everglades Agricultural Area (EAA) has been identified as the greatest contributor of phosphorus (P) loading to the Everglades Protection Area (EPA). A substantial effort in Best Management Practice (BMP) research, implementation, and education has been directed at reducing this P loading. BMP initiatives conducted to date include projects that address water, fertilizer, sediment, pasture management, and biological measures, as well as urban practices and chemical treatments. The initiatives can be categorized into BMP research projects, regulatory programs, and educational activities. Some research initiatives involving water, fertilizer, and sediment management were conducted at limited scales (plot size) and others at farm-scale. The first plot-scale BMP study, sponsored by the South Florida Water Management District (District), demonstrated that a few specific water and fertilizer management practices were effective in reducing P export from the EAA organic soils. Subsequently, ongoing farm-scale studies initiated in 1992 and sponsored by the EAA-Environmental Protection District (EAA-EPD) also show varying degrees of effectiveness in reducing P runoff from the implementation of combinations of water, fertilizer, and sediment management practices.

The overall effectiveness of BMPs is best demonstrated by measurements of the collective EAA Basin P reduction. Due to BMP implementation by the EAA landowners, the total phosphorus (TP) load from the EAA has declined in recent years compared to loads measured during a 10-year pre-BMP period (Water Years 1980 {WY80} through WY88 or Calendar Years 1979 through 1988). Since BMPs were required to be fully implemented four years ago, the total cumulative measured P loads attributable to the EAA have been reduced by 54 percent (preliminary WY99 data) as compared to the calculated load that would have occurred during the pre-BMP period (adjusted for hydrologic variability). The P load reduction represents a decrease of P from the EAA farms, cities and industry. The calculation does not equate to a 54 percent reduction of the TP entering the EPA from the other sources passing water through the EAA, such as Lake Okeechobee releases and C-139 Basin runoff (**Chapter 4**). The pre-BMP period load calculations are a result of a complex regression equation developed from actual measured loads during the pre-BMP period. BMPs implemented to date have been documented to be effective at the farm level. The combined efforts of research, education and the Everglades BMP Regulatory Program are responsible for appreciable reductions in the load and concentration of TP conveyed to the EPA attributable to the EAA.

Since last year's Chapter 5 summary, new information has been made available. A recent research initiative on suspended particulate transport by water (**Appendix 5: Summary Reference No. 7**) indicates that an average of about 60 percent of TP leaving farms in drainage water can be attributed to particulate matter. The study reported that the particulate-P found in farm drainage water comes primarily from floating aquatic macrophytes rather than from traditional soil erosion and bed-load movement. This study suggests that practices to manage floating macrophytes such as: weed booms in front of structures, or harvesting the plants, can be used to extract P from the water and redistribute organic matter on fields. A second

research project on particulate transport by wind (**Appendix 5: Summary Reference No. 16**) concluded that the threshold wind velocity for EAA organic muck soils is approximately one half of the common threshold wind velocity for mineral soils. The project also reported that keeping 30 percent of the soil surface covered with crop residue would reduce soil losses due to erosion by 70 percent. Based upon this information, wind breaks and reduced/minimum tillage may potentially reduce wind erosion and improve water quality. Two new research projects, soil P extraction investigations (**Appendix 5: Summary Reference No. 17**) and sugarcane variety P experiments (**Appendix 5: Summary Reference No. 13c**) have been initiated. Considering this recent information and as experience and information continue to be gained on the performance of existing BMPs, improvements in effectiveness are probable.

INTRODUCTION

A significant component of the Everglades restoration effort is to improve the quality of water entering the EPA. P has been identified as the nutrient most responsible for the changes occurring in the downstream natural areas (**Chapter 3**). Agricultural and urban BMPs are the source-control cornerstones to improving the quality of water being discharged into the District's water management system and subsequently entering the EPA. The 1994 Everglades Forever Act (Act, Section 373. 4592(2)(a), Florida Statutes) defines a BMP as the following:

> "… a practice or combination of practices determined by the District, in cooperation with the department, based on research, field-testing, and expert review, to be the most effective and practicable, including economic and technological considerations, on-farm means of improving water quality in agricultural discharges to a level that balances water quality improvements and agricultural productivity."

In addition to the EAA, other basins contributing stormwater to the EPA are being monitored for water quality under the Everglades Stormwater Program (**Chapter 11**). At some time in the future, results from the monitoring will assist in determining if BMP programs are appropriate in these other basins. Until such a time, BMP effectiveness reporting will focus solely on the EAA Basin.

The objective of this chapter is to summarize past and current BMP research, implementation and education programs and to characterize their association with P discharges from the EAA Basin. The chapter represents a status report on BMP effectiveness in the EAA. This year's chapter is a continuation of the information contained in Chapter 5 of last year's Everglades Interim Report (SFWMD, 1999b). Literature searches are continuing to capture any new information on BMP performance. The recommendations and conclusions presented in this year's chapter do not vary substantially from those reported last year since only nine months of additional data have been collected and analyzed. However, two new EAA research efforts were initiated that could influence subsequent recommendations and conclusions on the effectiveness of BMPs.

BACKGROUND

The Act provides for Everglades restoration through research, land acquisition, construction, and regulation. The Act mandates that the effectiveness of BMPs for reducing P loads be assessed, and possible impacts associated with water-quality parameters other than P be identified and reduced. The Act also requires that the District conduct research in cooperation with the EAA landowners to identify water quality parameters that are not being significantly improved by either the Stormwater Treatment Areas (STAs) or BMPs, and to identify further BMP strategies needed to address these parameters. The requirements of an agricultural privilege tax for EAA landowners are defined in the Act to facilitate land acquisition and construction of treatment areas. In conjunction with the tax, a system of incentive credits is established based on performance of implemented BMPs. The District developed a database in 1996 to capture data on existing BMP research (including District-sponsored BMP research that began in 1985). Data from BMP research projects being conducted by private companies, the EAA-EPD, the District, and various other federal and state agencies are compiled in the database as they become available.

Research and monitoring associated with evaluating the ecological and hydrological needs of the EPA (**Chapters 2, 3**), STA optimization (**Chapter 6**), and BMP effectiveness is targeted for completion no later than December 31, 2001. Results from this research and monitoring will allow DEP to propose a P criterion in the EPA, and to evaluate existing state water quality standards and classifications applicable to the EAA canals (**Chapter 1**).

BMP INITIATIVES APPROACH

Numerous sources were searched for publications pertaining to water quality and BMPs in the EAA. More than 70 such publications are available for review at the District's main library and the Everglades Regulation Division library. Remote-access, computerized searches were also performed using the Florida universities Library User Information System and various search engines on the Internet. The search identified more than 30 references on BMP research, implementation, and education projects specific to the EAA Basin.

The criteria considered for including a BMP study or program in this chapter were that the program or study:

- Was conducted or initiated during the period May 1979 to April 1999
- Was performed in, or addresses, the EAA
- Presents findings that were, or potentially may be, implemented as BMPs
- Documents or contains data and/or analyses that are complete and available for review

HydroScience Water Resource Consultants, Ltd. conducted a literature search and summarized BMP efforts in 1998 under contract to the District. The final report has been used as the foundation in the development of this chapter. Literature searches are continuing to capture any new information on BMP performance. Reference materials meeting the criteria described above, are summarized in this chapter. Multiple references from the same project were combined into a single “BMP initiative.” The initiatives can be categorized into BMP research projects, regulatory programs, and educational activities. Some research initiatives involving water, fertilizer, and sediment management were conducted at limited scales (plot size) and others at the farm scale. Research initiatives on management practices that are not currently BMPs, but may lead to the development or identification of future BMPs, are also included. Water, fertilizer, sediment, and pasture management as well as urban BMPs have been implemented basinwide through the regulatory initiatives (Rules 40E-61 and 40E-63 of the Florida Administrative Code). Additional initiatives have been undertaken to educate agricultural and urban communities within the EAA on BMP implementation and how to document effectiveness.

Table 5-1 lists select information for each initiative including the BMPs addressed, extent and period of implementation, and review-summary index number. The research, implementation, and education initiatives address water, fertilizer, sediment, pasture management, and biological measures as well as urban practices and chemical treatments. At least 10 private and/or public entities participated in the BMP projects since 1985 to reduce P loading from the EAA.

Table 5-1. Initiatives undertaken between 1979 and 1999 to address BMPs in the EAA.

Initiative	Best Management Practice[a]									
Summary No.[c]	Water Mgmt	Fertilizer Mgmt	Sediment Mgmt	Pasture Mgmt	Biological Measure	Chemical Trtmt	Urban	Extent of Implementation[b]	Program / Study	Implementation Period
1	I	I	I	I			I	Basin	Rule 40E-61, F. A. C. Rule 40E-63, F. A. C.	1989 – present 1992 – present
2	R	R						Precursor	Plot-Scale BMP Testing (limited BMPs)	1985 – 1991
3	R							Precursor	Water Management Study	1990 – 1991
4			R					Precursor	Sediment Control Research	1992 – 1995
5	R							Farm	Modified Pump Practices	1991 – 1994
6			R					Farm	Sediment Control Demonstration	1993 – 1995
7	R --	R --	-- R					Farm Potential	Farm-Scale BMP Implementation	1992 – present
8			R					Farm	Sediment Trapping in Rock Pit	1997 – 1998
9	E	E	E					Basin	Procedural Guide to BMPs	1993 – present
10	E	E	E					Farm	BMP Workbook and Training	1993 – present
11	E	E	E	E			E	Farm	BMP Demonstration and Education	1996 – present
12						R		Potential	Reduction by Precipitation and Coagulation	1992
13a & b 13c					R R			Potential Potential	Leaf Phosphorus Variability and Sugarcane Genetics	1992 – 1999 1999 – present
14						R		Potential	Chemical Dosing and Vegetative Treatment	1992 – 1996
15	R				R			Potential	Sugarcane Water Tolerance	1996 – present
16			R					Potential	Wind Erosion BMP Evaluation Tool	1997 – 1999
17		R						Basin	Soil P Extraction	1999 – present

a. I = BMP implemented through referenced program
R = BMP research project
E = BMP education project or program
b. Basin = Basinwide extent of implementation
Precursor = Work that led to implemented BMPs
Farm = Farm-level extent of implementation
Potential = Work that may lead to future BMPs
c. Reference number for narrative descriptions of initiatives in Appendix 5.

Summaries of the BMP initiatives are provided as an Appendix to this report. Fifteen categories of information are provided in each initiative summary:

- **Summary Reference No.:** Sequence number cross-referenced to **Table 5-1** and **Figure 5-12**.
- **Citation No.:** Bibliographic-sequence number cross-referenced to the **Literature Cited** section of the report that identifies the source of information summarized.
- **Project Type:** Denoted by "Program Implementation" in which BMPs are implemented through a referenced program; "Research" from which study results have resulted in, or may likely result in, a BMP; and "Education" which demonstrates BMP implementation.
- **Title:** Short description of the project, program, or initiative.
- **Author / Affiliation:** Lead author(s) identified in referenced citations.
- **Agency / Funding Source:** Entity(ies) identified as contributing funding to the research effort or program development.
- **Research Funding:** Estimated amount of funds (by source) contributed and/or budgeted between May 1979 and September 1998 for BMP-related research. Does not include in-kind support or services, which have been provided by private entities on several initiatives. Information that was unavailable or could not be verified by a mail survey is identified as "Not Available."
- **Objective:** Description of what the initiative planned or plans to accomplish.
- **Period of Implementation:** The period of time during which the initiative was performed.
- **Study / Program Area:** Denoted by "Basin-Scale" for work addressing the entire EAA, "Plot-scale" for work performed on small acreage areas, and "Farm-scale" for work on sub-basin sized areas that are significantly larger than plots.
- **BMPs Addressed:** Denoted by practices that address water management, fertilizer management, sediment management, pasture management, chemical treatment, and urban management.
- **Research / Program Design:** Description of the approach used to perform the initiative.
- **Major Findings:** Description of key results published for the initiative.
- **Extent of BMP Implementation:** Denoted by "Basinwide" for BMPs implemented throughout the EAA, "Precursor" for small-scale research studies that provided information on BMPs that were then implemented basinwide, "Farm Level" for BMP research and implementation on some farms within the EAA, and "Potential Precursor" for small-scale research studies that may provide information resulting in future BMPs.
- **Summary:** Assessment of the contribution an initiative has made to an understanding of BMPs and their effect on the load and concentration of P discharged from the EAA to the EPA.

Table 5-2 is a listing of all the BMP initiatives and their estimated or reported percent P load reductions for each individual BMP or combination of BMPs at the farm or basin level. Limited individual BMP performance information that has been derived directly from data analysis is currently available. Ongoing farm-scale research, basin-scale implementation and education programs are somewhat limited in being able to describe individual BMP performance since similar combinations of BMPs have been implemented basinwide under Rule 40E-63, Everglades BMP Regulatory Program.

Table 5-2. Best Management Practice initiatives' TP load reduction: measured findings or estimates.

Type of Initiative	Initiative	Banding at a Reduced Rate vs. Broadcast	Calibrated Soil Test	Prevention of Misplaced Fertilizer	Split Application and Slow Release Fertilizer	Slow vs. Fast Drainage	Minimizing Water Table Fluctuations	Retention of Drainage	Rice vs. Flooding Fallow	Use of Aquatic Cover Crops	Sediment Control	Sugarcane Genetics	Chemical Treatment	Pasture Management	Urban	Collective BMPs (no separation of types)
Implementation	Rule 40E-61, F.A.C. Rule 40E-63, F.A.C. (Landowner implementation of BMPs under Rule)	- -[a]	- -	- -	- -	- -	- -	- -	- -	- -	- -			- -	- -	49% (Basin)
Research	Plot-Scale BMP Testing (does not include sediment BMPs)	15%				30%			38%							20-60%[b] (Basin)
	Water Management Study							57%								
	Sediment Control Research Plot and Demonstration										17-68%					
	Modified Pump Practices							^[c]								
	Sediment Control Demonstration										^					
	Farm-Scale BMP Implementation	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -					4-40% (Farm)
	Sediment Trapping in Rock Pit										26%					
	Reduction by Precipitation and Coagulation												^			
	Leaf P Variability and Sugarcane Genetics											^				
	Chemical Dosing and Vegetative Treatment												^			
	Sugarcane Water Tolerance							^				^				
	Wind Erosion Evaluation Tool										^					
	Soil P Extraction		^													
Education	Procedural Guide to BMPs (includes sediment BMPs)	0-40%[b]	0-25%[b]	0-15%[b]	0-10%[b]		0-50%[b]	15-90%[b]		5-20%[b]	5-50%[b]					20-60%[b] (Basin)
	BMP Workbook and Training															^
	BMP Demonstration and Education															^

a. - - indicate individual BMP percent TP load reductions have not been determined or may not be possible to determine from data since combinations of BMPs have been implemented.

b. Percent TP load reduction was based upon professional judgment estimation, not directly substantiated with data.

c. ^ indicates that research or educational program was not conducted in such a manner to determine percent TP load reduction.

CHRONOLOGY OF MAJOR BMP INITIATIVES

BMP research, implementation, and education to reduce the discharge of TP from the EAA has been under way since the first initiative began in 1985. Nine initiatives had begun by 1992. Though each BMP initiative is listed in **Table 5-1** and summarized in **Appendix 5**, the relative significance and limitations of some major initiatives will be discussed in more detail in this section.

Four major initiatives are described in chronological order below. These initiatives are Plot-scale BMP Research; Everglades BMP Regulatory Program, Rule 40E-63; Farm-scale BMP Research; and BMP Education.

PLOT-SCALE BMP RESEARCH

(Appendix 5: Summary Reference No. 2)

Project Design and Objectives

The first plot-scale project was designed to identify and screen potential BMPs and study the physical and management mechanisms to reduce TP discharge from EAA farms in 1985. This plot-scale research was sponsored by the District and contracted to the University of Florida, Institute of Food and Agricultural Sciences (U of FL/IFAS). Project funding was provided primarily by the District with substantial monetary and in-kind contributions from the Fruit and Vegetable Growers Association and the Florida Sugar Cane League. Four specific conditions were tested on 1.4-acre plots: (1) sugarcane vs. drained fallow fields; (2) broadcast fertilization on cabbage crop vs. banding at a reduced rate; (3) fast vs. slow drainage rates for sugarcane; and (4) rice vs. flooding fallow following vegetable production. These plots were established on organic soil farmland with typical agricultural production practices in the EAA.

Major Findings and BMP Screening

Three of the four conditions tested were identified as BMPs that reduced TP loads in runoff: drainage rate for sugarcane (reduce pumped volumes while removing water quickly and uniformly); banding fertilization on cabbage; and off-season rice production. No reduction in TP load was observed for the fourth tested condition that compared drainage from sugarcane and continuously fallow plots.

Summary of Plot-Scale Research

This research investigated BMPs in two categories – water management and soil fertility management. The research results led to the conclusion that primary BMPs relate to limiting fertilizer usage, managing water tables and drainage pumping, and growing harvested aquatic P sink crops when land is normally flooded fallow. It was estimated, using best professional judgment, that from 20 to 60 percent TP reductions could be achieved from pre-BMP (without BMPs) levels at the basin level, and drainage volume BMPs could be responsible for about a 20 percent loading reduction. These original basin reduction estimates did not include the effectiveness to be gained from sediment control BMPs. Although effectiveness was demonstrated for a few specific BMPs at the plot-scale, the study clearly indicated at its conclusion in 1991 the need for additional research to characterize impacts of BMP implementation at the farm-scale.

After the conclusion of the plot-scale study, farm-scale BMP research was initiated in 1992 on water and fertilizer management strategies (primarily sponsored by the EAA-EPD). Before BMP performance information was available from these farm-scale projects, the implementation of Rule 40E-63, Everglades BMP Regulatory Program was required.

EVERGLADES BMP REGULATORY PROGRAM, RULE 40E-63

(Appendix 5: Summary Reference No. 1)

This section provides a summary of the Everglades BMP Regulatory Program. For additional information, the District's Everglades Regulation Division publishes an annual status report, which provides in greater detail an explanation of the program's various components and data evaluation. For a copy, contact the District's Environmental Resource Regulation Staff.

Regulatory Background

The basinwide implementation of BMPs by EAA growers is the primary component of the Everglades BMP Regulatory Program. This program was developed by the District during 1991 and 1992 as directed by the Everglades Protection Act (now the Everglades Forever Act). The BMP program was developed through a series of public workshops and round-table discussions. The two-year effort resulted in Chapter 40E-63, Florida Administrative Code (F.A.C.), which describes the intent, requirements, and compliance components of the Everglades BMP Regulatory Program. The BMP program requires that each landowner implement on-site BMPs to reduce P leaving their property. EAA basinwide BMP implementation was mandated to begin in 1994 and was required to be completed on all land areas by January 1995 (Rule 40E-63). The goal of the BMP Regulatory Program is a 25 percent annual TP reduction from the EAA as compared to a pre-BMP implementation base period, October 1, 1978 – September 30, 1988 (complete WY80 through WY88). The program for the EAA is unique in that its goal is to achieve a 25 percent reduction in P for the entire EAA Basin as a whole, not for each individual internal drainage basin. The District determines if a 25 overall reduction has occurred by comparing P discharges for any 12-month period with a pre-BMP period of record. The first annual compliance period was May 1, 1995 through April 30, 1996.

Program Implementation

The BMP Regulatory Program requires that each landowner submit a plan of on-site BMPs to reduce P leaving their property. Typical BMP plans incorporate improved practices of fertilizer application, improved water management including detention, and control of soil erosion. The BMP program includes follow-up verification of the approved BMP plans on two levels: (1) Annual BMP implementation report and (2) BMP field verification. Annual reports summarize the initial implementation of BMPs and the ongoing maintenance and documentation. BMP field verifications are conducted to ensure that the BMPs as approved by permit and reported in the annual BMP reports have been implemented. Site verifications allow District staff to work with the landowners by discussing BMP strategies and communicating areas of concern (if any). The BMP site verifications conducted thus far indicate that the permittees have implemented their respective BMP plans and are taking a proactive approach to reviewing and improving their plans where possible. One hundred and twenty-three BMP site verifications were conducted during WY98, and totaled 270,624 acres.

Permitting. Part of each permit application, as mentioned above, requires the landowner to submit a proposed plan of on-site BMPs. Acceptable BMPs include operational programs or physical enhancements designed to reduce P leaving their property.

The District wanted to (a) establish a base level of BMPs for each permit area and (b) ensure consistency with BMP plans between different landowners. To accomplish both of these criteria, a system of BMP "equivalents" was developed. The intent was to assign "points" to BMPs within three basic categories: fertilizer techniques, water management, and sediment control (**Table 5-3**). At the time, information on the P reduction potentials of individual BMPs in the EAA region was limited. The BMP list and points assigned to each BMP were based almost solely upon the best profes-

Table 5-3. BMP summary and "BMP Equivalent" points.

BMP	Points	Description
WATER DETENTION		
½ Inch Detained	5	• Increased detention in canals, field ditches, soil profile, fallow fields, aquatic cover crop fields, prolonged crop flood; • Measured on an annual average basis rainfall vs. runoff
1 Inch Detained	10	
FERTILIZER APPLICATION CONTROL	2 ½	Uniform and controlled boundary fertilizer application (e.g. direct application to plant roots by banding or side-dressing; pneumatic controlled-edge application such as AIRMAX)
FERTILIZER CONTENT CONTROLS		
Fertilizer Spill Prevention	2 ½	• Formal spill prevention protocols (handling and transfer) • Side-throw broadcast spreading near ditch banks
Soil Testing	5	Avoid excess application by determining P levels needed
Plant Tissue Analysis	2 ½	Avoid excess application by determining P levels needed
Split P Application	5	Apply small P portions at various times during the growing season vs. entire application at beginning to prevent excess P from washing into canals (rarely used on cane in EAA)
Slow Release P Fertilizer	5	Avoid flushing excess P from soil by using specially treated fertilizer which breaks down slowly thus releasing P to the plant over time (rarely used in EAA)
SEDIMENT CONTROLS		EACH SEDIMENT CONTROL MUST BE CONSISTENTLY IMPLEMENTED OVER THE ENTIRE ACREAGE
Any 2	2 ½	• Leveling fields • Ditch bank berm • Sediment sump in canal • Strong canal cleaning program • Field ditch drainage sump • Slow field ditch drainage near pumps • Sump upstream of drainage pump intake • Cover crops • Raised culvert bottoms • Veg. on ditch banks • Other BMP
Any 4	5	
Any 6	10	
OTHER		
Pasture Management	5	Reduce cattle waste nutrients in surface water runoff by "hot spot" fencing, provide watering holes, low cattle density, shade, pasture rotation, feed & supplement rotation, etc.
Improved Infrastructure	5	Uniform drainage by increased on-farm control structures
Urban Xeriscape	5	Lower runoff and P by using plants that require less of each
Det. Pond Littoral Zone	5	Vegetative filtering area for property stormwater runoff
Other BMP Proposed	TBD	Proposed by permittee and accepted by SFWMD

sional judgment of the District's Everglades Regulation Division staff.

Twenty-five BMP equivalents or points were set as the minimum target BMP level. Utilizing the BMP equivalents approach allowed flexibility of each landowner to develop a BMP plan that was best suited for site specific geographic and crop conditions. **Table 5-4** compares "BMP equivalent" plans for four different landowner permit basins, showing the flexibility of this approach. Even though each basin had different land uses, soil types, and drainage capacities, point-equivalent BMP plans were successfully developed and accepted.

Table 5-4. Example of "BMP Equivalent" plans for four different landowner basins.

BASIN 'A' (Sugar Cane, deep soils)	
BMP	**Points**
Water Detention 1 ½ inch	15
Fertilizer – Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Fertilizer Banding	5
TOTAL	25

BASIN 'B' (Sugar Cane & Vegetables, medium soils)	
BMP	**Points**
Water Detention -- 1 inch	10
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Fertilizer Pneumatic	5
Sediment Controls – any 4	5
TOTAL	25

BASIN 'C' (Sod, medium soils)	
BMP	**Points**
Water Detention -- 1 inch	10
Fertilizer – Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Sediment Controls any 6	10
TOTAL	25

BASIN 'D' (Citrus, shallow soils)	
BMP	**Points**
Water Detention – $^1/_2$ inch	5
Fertilizer -- Soil Testing	2 ½
Fertilizer -- Spill & Misapplication Prevention Program	2 ½
Sediment Controls – any 4	5
Other -- Improved Infrastructure	5
Other -- Low volume drip irrigation	5
TOTAL	25

Post Permit BMP Activities. After the BMP permit plans are approved, Rule 40E-63 requires follow-up post-permit verification of the approved BMP plans on two levels: 1) BMP implementation reports and 2) BMP field verification. Annual BMP implementation reports are required by Rule 40E-63 to be submitted to the District; they summarize not only the initial implementation of BMPs, but ongoing BMP maintenance and documentation.

District Everglades Regulation Section staff conduct BMP site verifications on an 18-month rotational basis to allow examination of BMPs implemented in both wet and dry seasons. Field verification procedures begin with generating a database driven BMP checklist specific to the permit drainage basin. The checklist consists of all BMPs selected by the permittee to be implemented. The checklist is mailed to the permittee prior to the verification to assist the landowner in preparing documentation for the inspection. The verifications involve a combination of visual field observations and a review of office records. During the office review, the District staff focus on records that document soil test results, fertilizer recommendations and applications, BMP training of farm personnel, pump logs and any other material that supports BMP implementation. While in the field, District staff note any visual evidence that the selected BMPs have been implemented. This evidence may range from spoil on canal banks indicating canal cleaning was performed, fertilizer banding or land leveling equipment operating, and maintenance of vegetation on ditch banks to reduce sedimentation or to any other observable evidence that supports BMP implementation.

Site verifications allow District staff to work with the permittees by discussing BMP strategies and communicating areas of concern (if any). The verifications are a snapshot in time of how and when BMPs were implemented for that particular field and land use. The District knows which types of BMP have been chosen by the landowner for each particular land use and location so a verification can be conducted. However, the interpretation of a BMP by one landowner may be drastically different from that of a neighboring landowner. Information on how specifically each BMP was implemented and operated on each field over the history of the program does not exist and is therefore unavailable to the District. Pre-BMP data are also not available to the District for the 200+ drainage basins within the EAA. At the farm level, neither implementation of additional BMPs nor examination and enhancement of existing BMPs are required until the basin level compliance fails to be met.

Extent of BMP Implementation

EAA basinwide BMP implementation was mandated to begin in 1994 and was required to be completed on all land areas by January 1995 (Rule 40E-63). **Figures 5-1 through 5-7** represent the spatial distribution of BMPs implemented by landowners. These maps document clearly that most of the drainage basins in the EAA have selected the same individual BMPs to fulfill the BMP plan minimum 25-point criteria. Although there are many specific BMPs (**Table 5-3**), **Figures 5-1 through 5-7** group the BMPs by seven major types:

- Basic fertilizer BMP (soil testing and spill prevention programs);
- Advanced fertilizer BMPs (controlled application {banding, pneumatic} split applications, slow release fertilizer);
- Rainfall detention (various amounts: $^1/_2$, 1 inch);
- Sediment controls;
- Urban practices (e.g. NPDES);
- Pasture management; and
- Infrastructure Improvements.

The first four listed types of BMPs have been implemented basinwide and the last three have been implemented at a smaller scale.

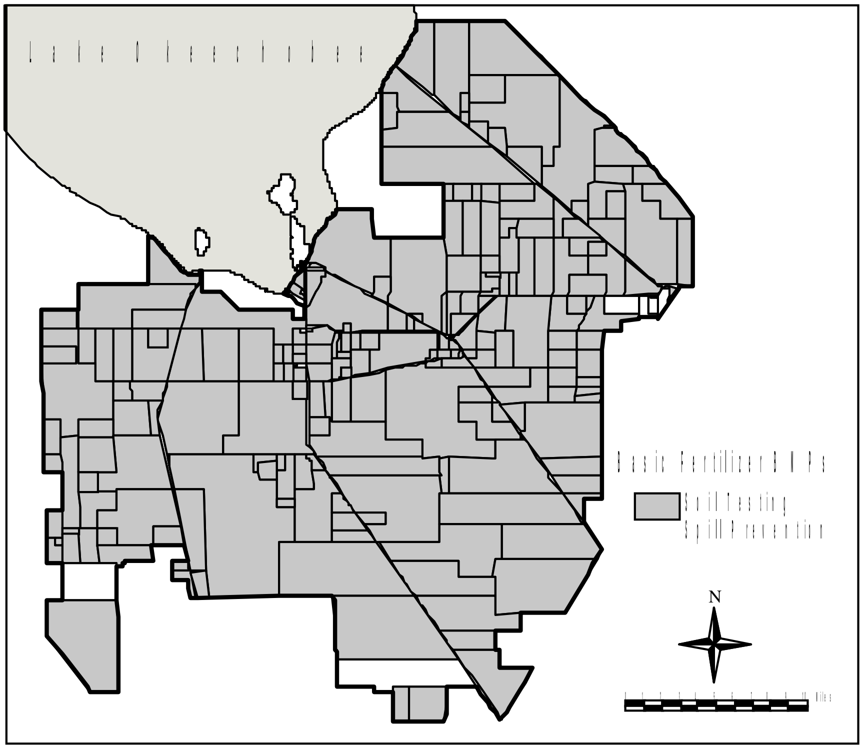

Figure 5-1. Location of basic fertilizer BMPs in the EAA.

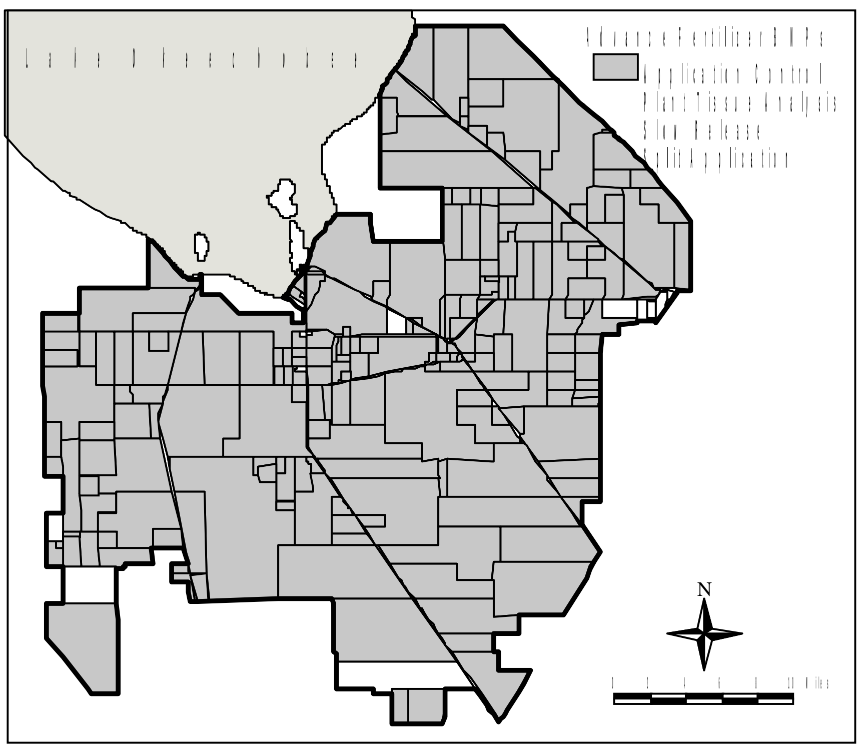

Figure 5-2. Location of advanced fertilizer BMPs in the EAA.

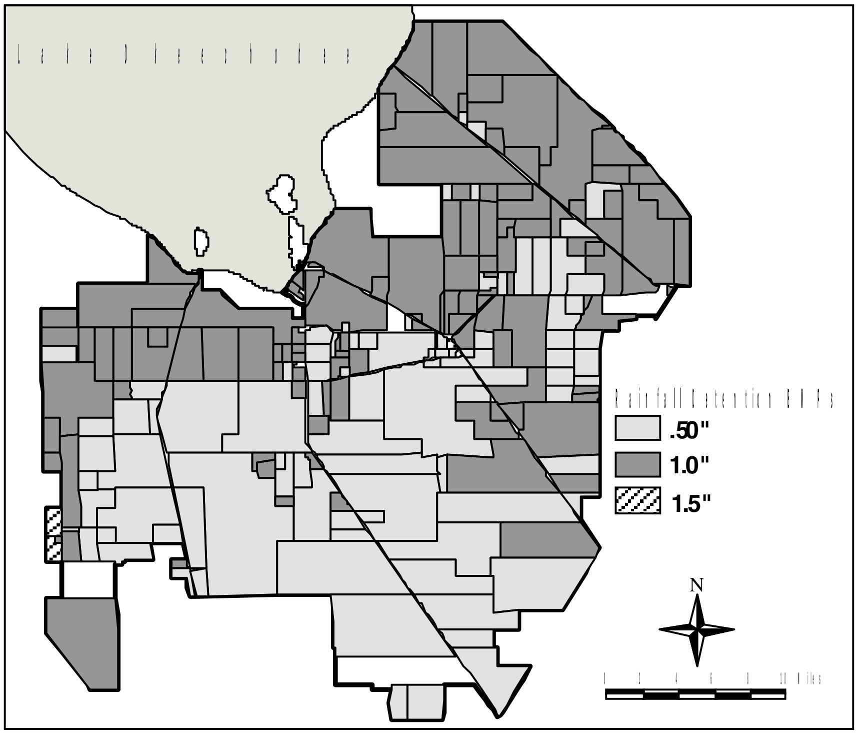

Figure 5-3. Location of detention BMPs in the EAA.

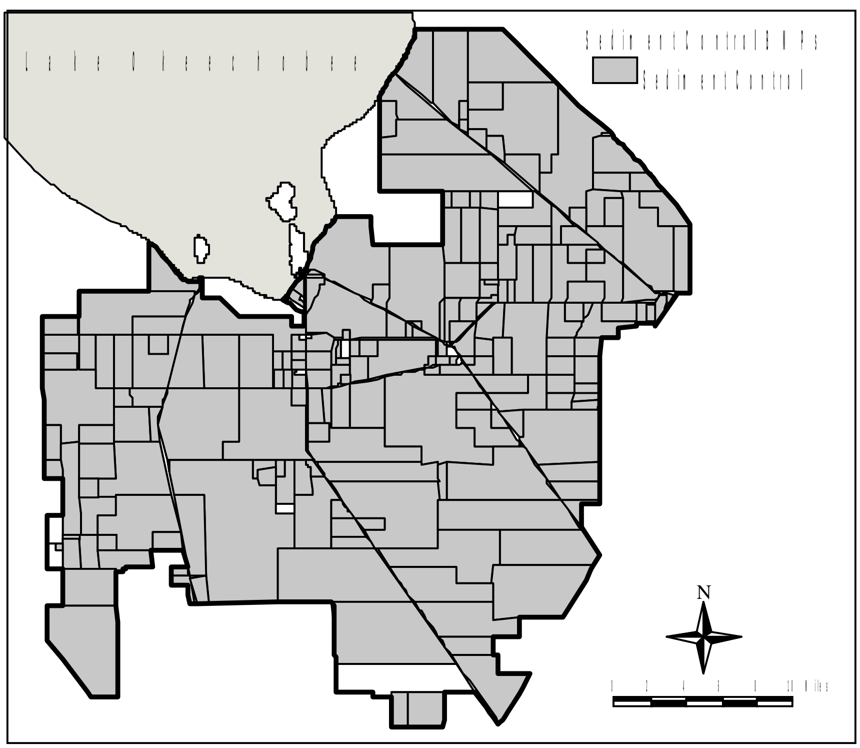

Figure 5-4. Location of sediment control BMPs in the EAA.

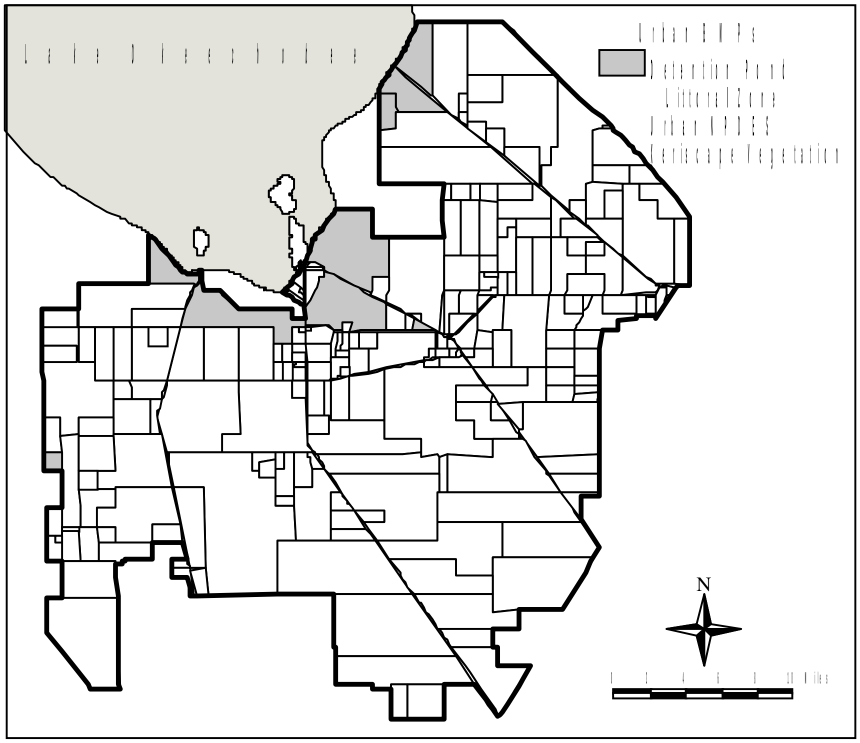

Figure 5-5. Location of urban BMPs in the EAA.

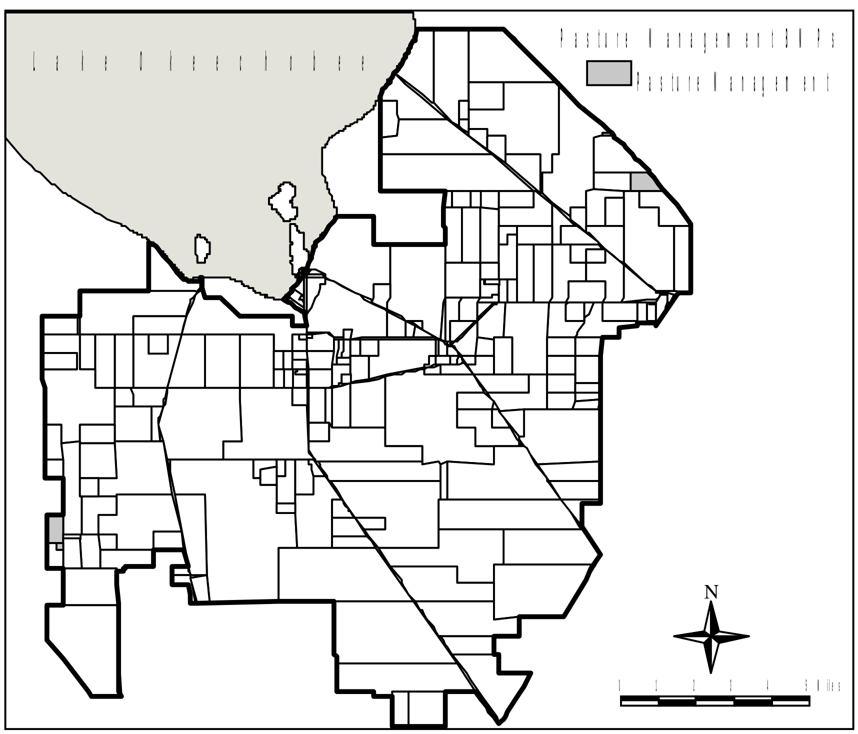

Figure 6-6. Location of pasture BMPs in the EAA.

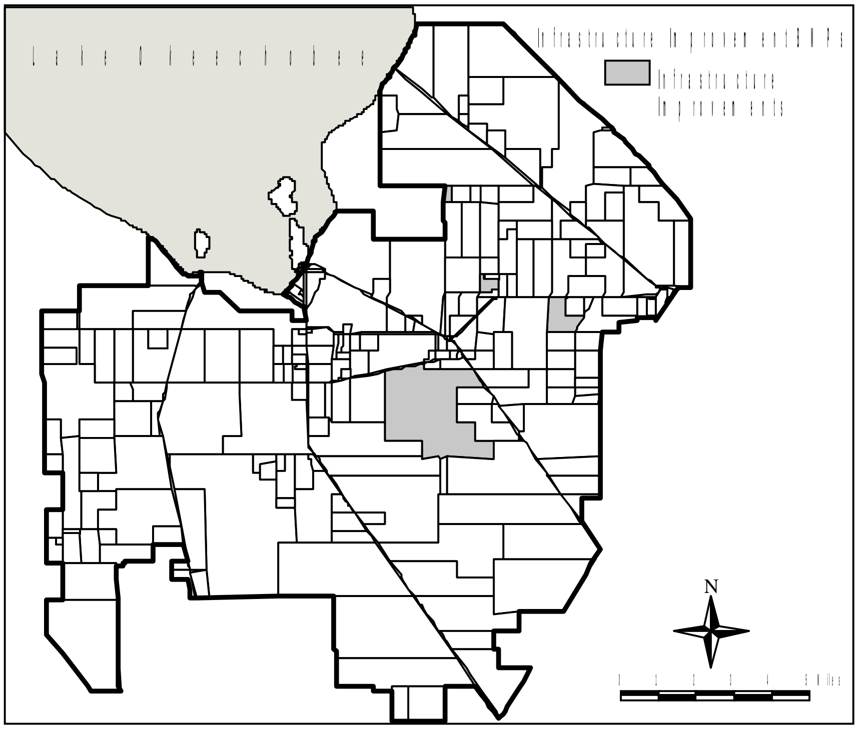

Figure 5-7. Location of infrastructure improvement BMPs in the EAA.

Monitoring the Effectiveness of BMP Implementation

Rule 40E-63 requires that water quality monitoring be conducted at two levels: (1) EAA Basin-level by the District, and (2) Landowner-level permit monitoring of private water control structures within the EAA. The primary means to determine the effectiveness of BMPs and the Rule 40E-63 program is through District collection and analysis of water quality data at the EAA Basin-level. The permittee-level water quality monitoring at individual drainage basins is a secondary means of measuring BMP program compliance. The data would only be used for compliance purposes if the EAA Basin does not meet the 25 percent reduction requirement.

Permit or Farm-Level Monitoring. Farm-level water quality, the secondary component of the Regulatory BMP Program, is assessed by monitoring data obtained by permittees. Annual average flow-weighted TP concentrations (parts per billion, ppb) and P load exports (pounds per acre, lbs/ac) have been calculated from the daily permit water quality monitoring data reported during WY98. **Figures 5-8** and **5-9** present the spatial distributions of P concentrations and P load discharges by permit drainage basin.

The permit-level water quality and discharge monitoring may allow for relative comparison between permit basins. Thus, these data and BMP information could be used to identify drainage basins that do not appear to be performing as well as other similar basins. With this in mind, assisting permittees that **voluntarily** would like to investigate the lesser BMP performances on their properties appears to offer potential for further load reductions. However, it may be very difficult to use this farm-level data to determine individual BMP performance, verify the “25-point” rating system

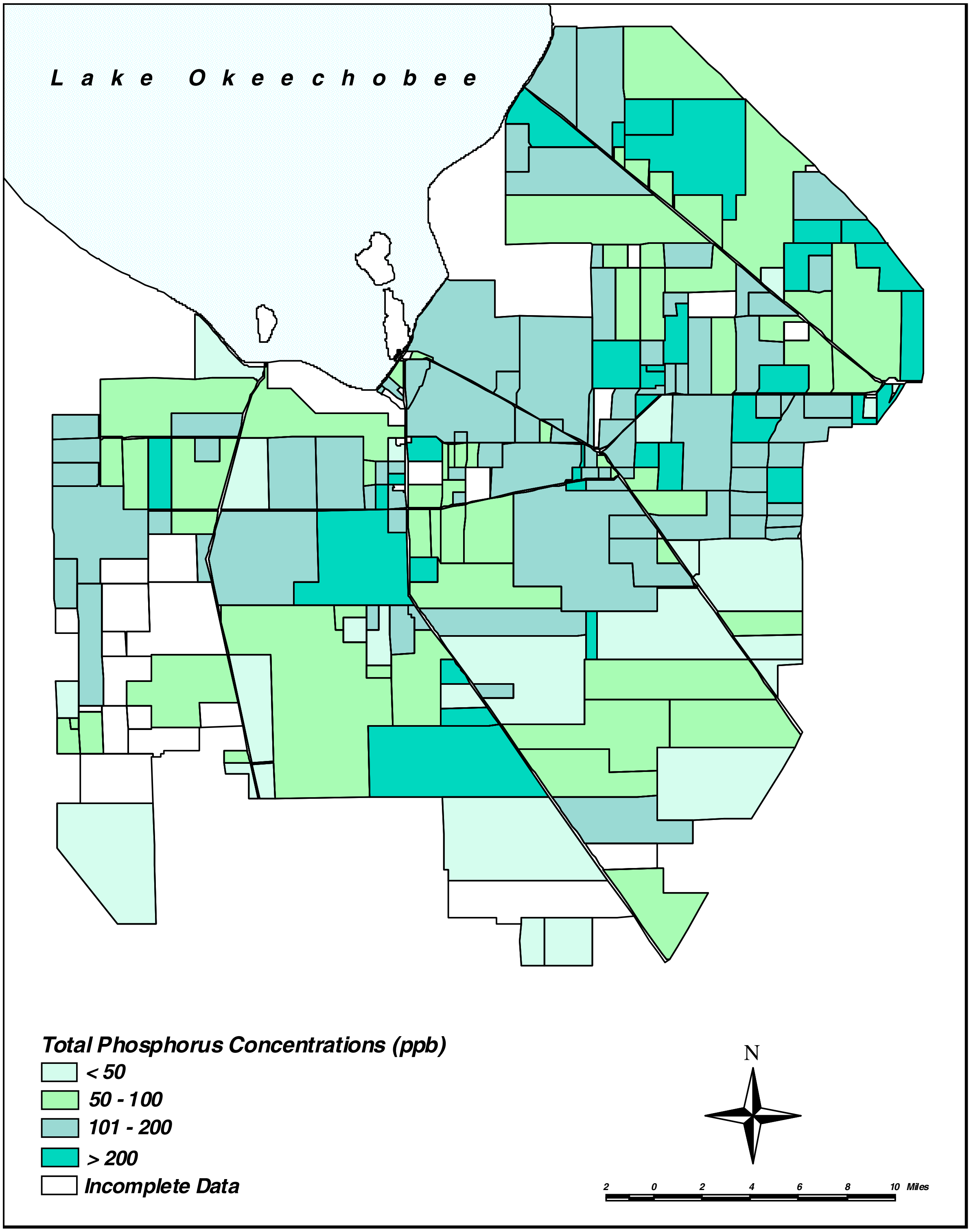

Figure 5-8. WY98 spatial distribution of TP concentrations from permit drainage basins.

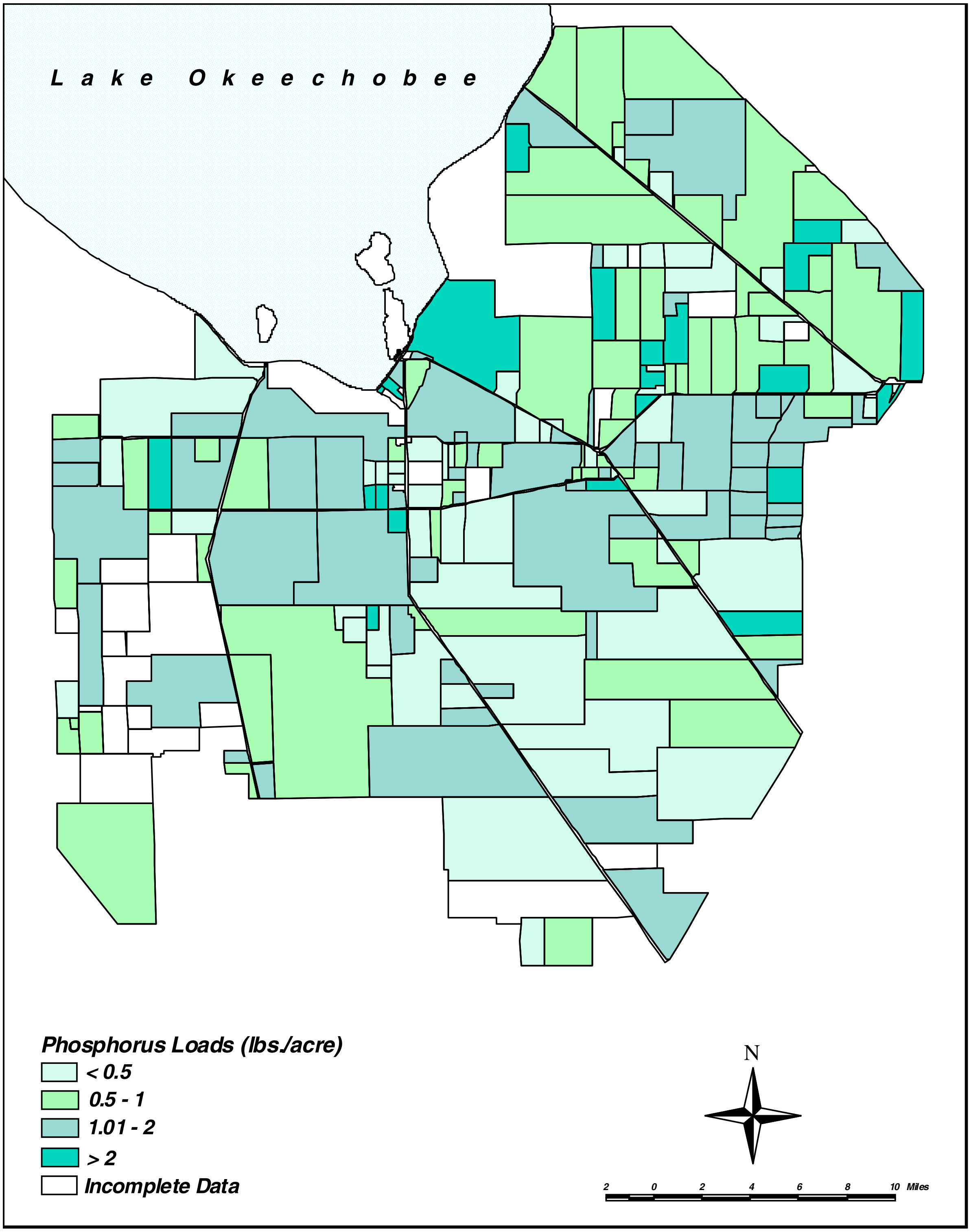

Figure 5-9. WY98 spatial distribution of TP loads from permit drainage basins.

and/or characterize the utility of the compliance data for the following reasons:

- Each farm-level data set represents the implementation of multiple BMPs.
- There is limited spatial variation in site-specific BMP information.
- Baseline period is only a single year.
- Permittee program does not track previous land uses, which may affect P discharges despite BMP implementation.
- One landowner's interpretation of a particular BMP may be different from that of another landowner.

In fact, it should be noted that the permittee-level water quality monitoring cannot be used to determine the measure of P discharged to the Everglades. The surface water discharged from any one of the 219 defined drainage basins may be withdrawn as irrigation or freeze protection water by another farm. On an annual basis, there exists a tremendous amount of recycling of water within the EAA prior to any discharge to the Everglades. This conclusion is supported by the fact that the average annual total volume of water discharged from the 300+ permittee or farm-level pump stations is approximately twice the volume released from the District water control structures surrounding the EAA.

Basin-Level Monitoring and Calculations. The EAA Basin-level monitoring is conducted by the District at structures moving water into the EPA or STAs. TP and flow measurements are recorded at large pump stations and water control complexes operated by the District (**Figure 5-10**). The P levels measured at these District structures collectively determine primary compliance for all permits. To interpret P measurements taken at the District pump stations and water control structures surrounding the EAA, it is important to recognize that water leaving the EAA pump stations is a combination of EAA farm and urban runoff and water passing through the EAA canals from external basins. The P loads must be carefully separated to draw accurate conclusions on the P loads originating from the EAA agricultural and urban activities. The results of the EAA Basin-level monitoring are discussed later in this section and additional data and information on EAA loading to the EPA can be found in **Chapter 4** of this report.

The Act mandates a specific method to measure and calculate the annual EAA export of P in surface water runoff from the EAA lands (farms, cities, and industry). Calculating a single year's P reduction requires more than simply comparing the average annual amount from the 10-year base period to a current year's value. Because rainfall and surface-water discharges vary with time and location throughout South Florida, an adjustment for these variations is made in the calculations. These hydrologic variabilities could be large enough to mask the measured effectiveness of the BMPs in reducing P loads. In a dry year, for example, the TP discharged from the EAA may be very low, which leads to the question of whether this is because of the BMPs or less rain. The hydrologic adjustment attempts -- to the greatest extent practicable -- to factor out annual rainfall variations so a direct comparison can be made between any current year's P load and that of the pre-BMP base period.

Methodology was developed during the 1991-1992 rulemaking effort for the Everglades Regulatory Program (Chapter 40E-63, F. A. C.) and is described in greater detail in the District's Everglades BMP Program annual status reports (Everglades Regulation Division, District). Entities represented at the workshops included state and federal agencies, agricultural industry, environmental organizations, Native American nations of Florida, and interested members of the general public.

In brief, the methodology compares the current year's measured P load in runoff that is attributable to the EAA farms, cities, and industry with BMPs in place, with a statistical prediction of what the P load would have been without the BMPs in place if

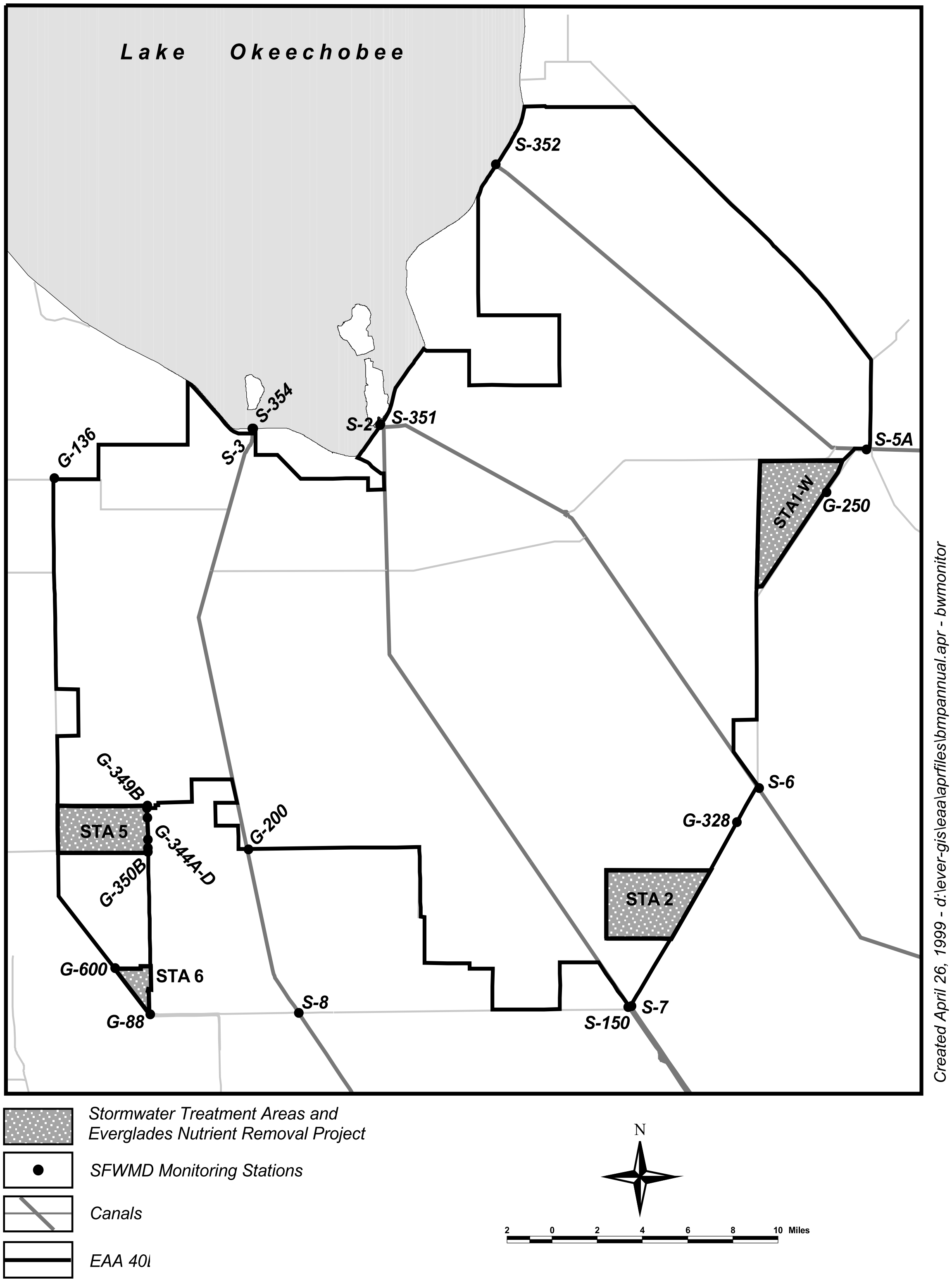

Figure 5-10. District water control structures within the 40E-63 boundaries.

the annual rainfall and distribution measured for a *current* year had occurred during pre-BMP base period. The statistical prediction equation ($r^2 = 0.91$) was developed using the EAA measured loads during a 10-year pre-BMP period. The annual P percentage reduction is computed by comparing the *current* year's TP load with the *predicted* average annual load for what the base period would have been had the current year's rainfall pattern occurred during the pre-BMP base period.

Figure 5-11 provides a graphical perspective of the EAA basin calculations conducted in accordance with Rule 40E-63. Each data bar represents the actual measured TP tonnage measured from the EAA each water year. The data line in **Figure 5-11** represents the predicted pre-BMP period average annual P levels by the methodology described earlier. The relative difference between the actual measured P tonnage (data bar) and the predicted pre-BMP average annual P tonnage (data line) is the percent P reduction.

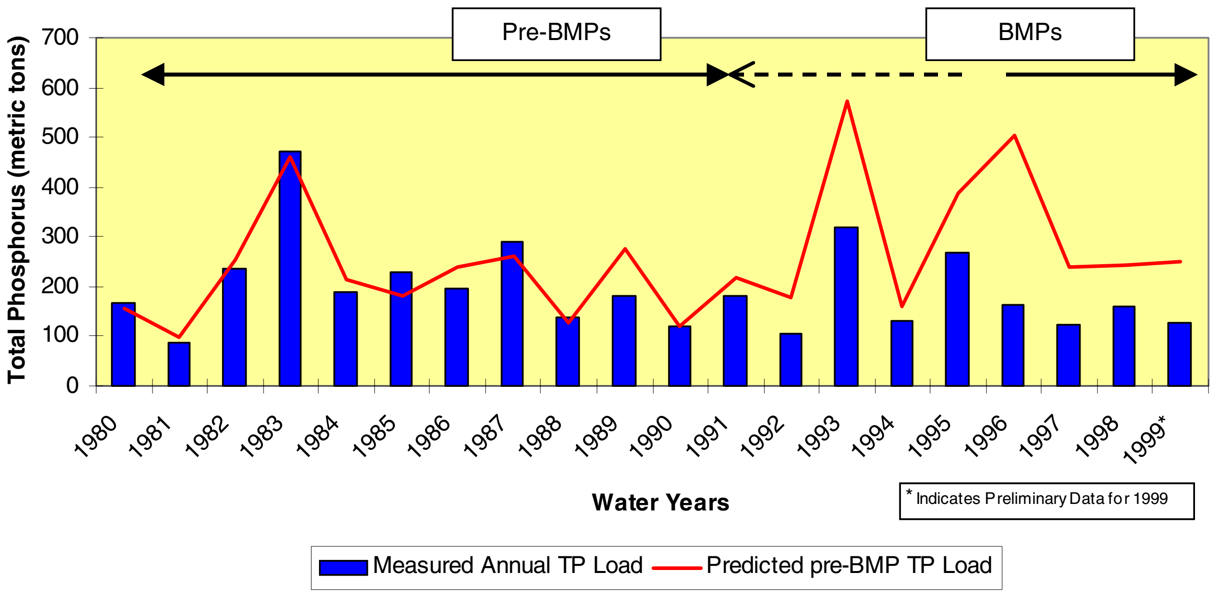

Figure 5-11. EAA basin TP load calculated as per criteria in Rule 40E-63, F.A.C.

As described, the annual percent reduction of P is calculated as the relative difference between the actual measured EAA basin P load and the predicted pre-BMP average annual P load. The annual EAA basin percent P reduction calculations are presented in **Figure 5-12.** The solid line shows the longer-term trend (three-year trend) of percent reduction, which tends to smooth the year-to-year variability. The ♦ symbols represent the annual measurement. The most recent three-year trend cumulative percent load reduction attributable to the EAA during WY97, WY98, and WY99 is 44 percent (preliminary WY99 data). The total cumulative measured P load reduction since BMPs have been required to be fully implemented (over the last four years) is 54 percent.

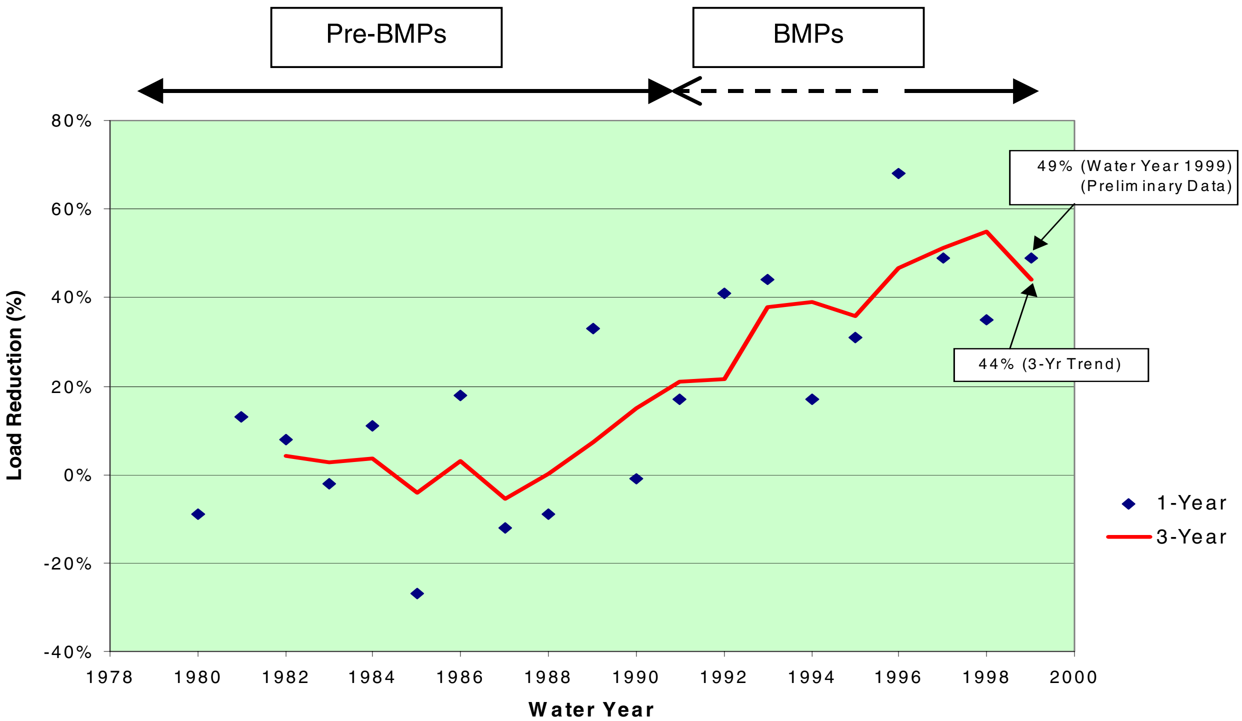

Figure 5-12. EAA basin TP percent reduction calculated as per criteria in Rule 40E-63, F.A.C.

FARM-SCALE BMP RESEARCH

(**Appendix 5: Summary Reference No. 7**)

In 1992, after the conclusion of the plot-scale study and after the initiation of the Everglades BMP Regulatory Program, farm-scale BMP research began on water and fertilizer management strategies. Note that plot-scale and demonstration studies on sediment control BMPs were also initiated in 1992 by the United States Sugar Corporation (**Appendix 5: Summary Reference No. 4**). The ability of a combination of selected BMPs to reduce TP discharge from agricultural areas has been demonstrated from these farm-scale studies. This farm-scale research was sponsored primarily by the EAA-EPD and contracted to the U of FL/ IFAS. Project funding was provided primarily by the EAA-EPD with supplemental monetary contributions from the Florida DEP (Environmental Protection Agency 319 Funds) and the District.

Project Design and Objectives

The objectives of the farm-scale research have evolved over time. The study was initiated in 1992 and has continued to date. The original focus was to measure baseline and post-BMP implementation P loads from different types and sizes of farms (10 farms ranging in size from 320 to 4,500 acres), and to evaluate P load response to weather. The 10 farms are representative of the EAA with respect to soils, crops, water and fertilizer management practices, and geographic locations **(Figure 5-13)**. Flow and P concentration were monitored for the baseline period from 1992 to about 1994 and for the BMP period from about 1995 to present. During more recent phases of the project, the scope of work has been expanded to include the evaluation of particulate P transport and the characterization of other water-quality parameters, notably particulate P, specific conductance, atrazine and ametryn.

Work has progressed in annual phases. Crop production on the selected plots varies from monocultures of sugarcane and vegetables to multi-cultures of vegetables, rice, sod and sugarcane. Consideration was taken to ensure proper implementation and maintenance of BMPs, not only to address BMP effectiveness, but also to prevent crop damage and/or loss that may result. Baseline TP concentrations, absolute loads, unit area loads (UAL) and net loads are developed for the 10 farms over a period of several years. BMPs implemented at the 10 farms are described in **Table 5-5**.

During Phases I and II (of eight phases to date), monitoring systems were installed and BMPs were implemented. Hydraulic BMPs alter hydraulics and drainage practices for irrigation/ drainage systems and were implemented first at four research plots because of their far-ranging effects. EAAMOD, a parametric water- and P-transport model of subsurface flow, was reviewed and modified for hydraulic conditions in the EAA.

During Phase III, a particulate P transport study was conducted by sampling several matrices including discharge water, suspended solids, surficial sediments, bed sediment, aquatic weeds and detritus. The particulate transport study continued during Phase IV with the formulation of sediment-control BMPs. An unsteady, open-channel flow model (DUFLOW) was modified to allow input of subsurface drainage, and used to simulate water and particulate transport.

During Phase V, two distinct philosophies emerged regarding the implementation of BMPs under prevailing hydraulic conditions. The first focuses on small rainfall events during which off-farm pumping may be considered as optional. The second focuses on the few major events that contribute the majority of the TP loading.

By Phase VI the hydraulic BMPs were implemented in combination with crop rotation, fertilizer management and sediment management at several test plots. Research was initiated in late 1997 to characterize other water-quality constituents pursuant to requirements of Part III, Chapter 40E-63, F. A. C. In-situ monitoring is conducted at all sites using a Hydrolab Datasonde 3, multi-parameter water-quality probe to measure temperature, dis-

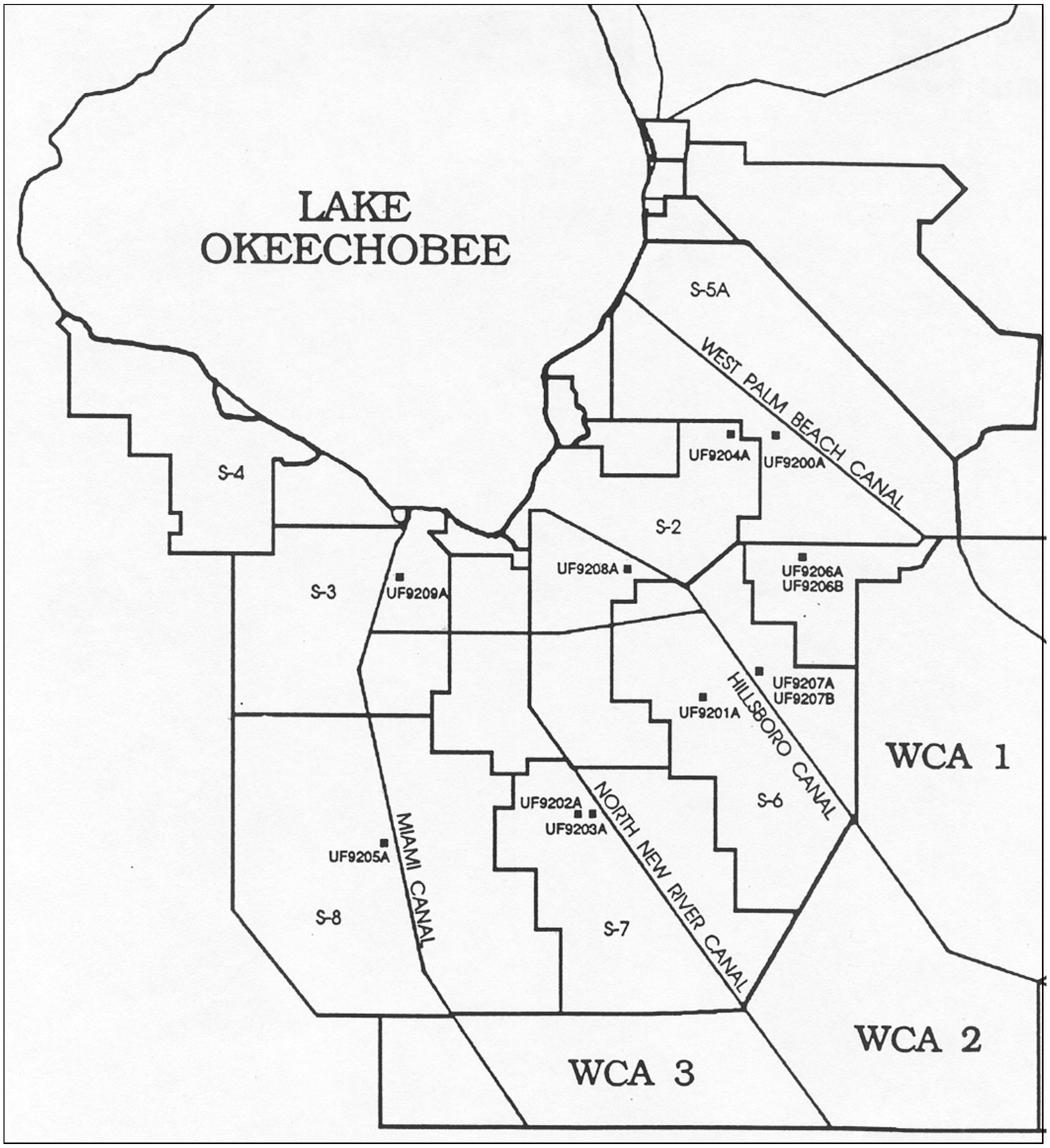

Figure 5-13. Approximate locations of EAA-EPD sponsored U of FL/IFAS experiment sites.

solved oxygen, pH, conductivity, and turbidity. EAAMOD-Field version 13.0 was released. EAAMOD-Field is simple to use and serves well to examine differences in BMP plans.

During Phases VII and VIII, EAAMOD-Farm (incorporation of EAAMOD-Field into DUFLOW) was calibrated using project data. Lysimeter studies began at a project site to study: (1) the effects of higher water tables on three different sugarcane varieties; (2) the effects of growing rice in rotation with vegetables on soils, crops, fertilizer requirements and P balances; (3) the effects of storing rice and fallow field drainage water on sugarcane and sugarcane fertility; and (4) the feasibility of using

Table 5-5. Summary of BMPs implemented in the 10 U of FL/IFAS experiment sites.

Site	Farm size (ha.)	Cropping system	Major BMPs
UF9200A	518	Sugarcane monoculture	Reduced frequency of irrigation/drainage events, attenuated water table micro-management, cleaned ditches, removed sedimentary material from ditch ways, calibrated soil test
UF9201A	518	Vegetable monoculture	Routed water internally from field block to field block during planting season, allowed summer fallow flood waters to reduce naturally through ET/percolation, calibrated soil test
UF9202A	130	Sugarcane monoculture	Improved drainage uniformity by installing internal booster pump, reduced off-farm discharge, minimum-tillage sugarcane planting practices, calibrated soil test
UF9203A	1865	Sugarcane/rice rotation	Installed control structures, increased farm drainage capacity, calibrated soil test
UF9204A	259	Sugarcane monoculture to sugarcane/rice rotation to sugarcane monoculture	Implemented new off-farm pumping protocol (1/95), rotated half of farm sugarcane acreage into rice (4/95) in absence of concurrent hydraulic BMP implementation, rotated melons back to fallow (10/95), calibrated soil test
UF9205A	130	Sugarcane monoculture to sugarcane/vegetable mix to sugarcane monoculture	Rotated almost half of farm sugarcane acreage into corn (3/94) followed by fallow and melons (5/95) in the absence of concurrent hydraulic BMP implementation, rotated melons back to fallow (10/95) and then sugarcane (2/96), calibrated soil test
UF9206A&B	710	Sugarcane/sod mix with vegetable/rice rotation	Installed control structures, blocked farm into six hydraulically isolated units, routed vegetable/rice draindown water to other areas of farm for storage and/or removal through ET/percolation, calibrated soil test
UF9207A&B	1012	Sugarcane/vegetable mix	Reduced drainage pumping chemical injection and diversion of water around farm, sediment trap/pit in main farm canal, calibrated soil test
UF9208A	106	Sugarcane monoculture	Increased on-farm retention in soil profile and open waterways, reduced drainage pumping, calibrated soil test
UF9209A	1243	Sugarcane monoculture	Reduced drainage pumping using strict protocols for triggering off-farm discharge, installed internal booster pump for improved drainage, calibrated soil test

high P water as fertigation (fertilizer in irrigation water).

Major Findings and BMP Efficacy

Phase I. The highest P concentrations were documented at two research farm sites located in the northeast section of the EAA. These findings emphasize the influence of soil type and rainfall intensity and volume on P concentrations.

Phase II. Pump calibrations[1] vary widely based on different methods and different persons using the same method. Baseline P-loading data documented major differences between stations. Little difference was observed in P concentrations between time and flow-weighted composite samplers; however, grab samples and incomplete composite samples yield major discrepancies that can affect calculated P loads.

Phase III. Baseline TP concentrations and unit-area loadings appear to be strongly dependent on

1.The above referenced pump calibrations are required for the ten-farm research data analysis and the Everglades BMP Regulatory Program. A Calibration Work Group comprised of professionals with specialized expertise in flow calibrations was subsequently formed by the District to develop calibration guidelines. The guidelines provide reasonable assurance that flow is accurately measured as required by the BMP Regulatory Program. The grab versus automated sampling difference also mentioned above has often been found in District monitoring (**Chapter 4**).

geographic location, crop rotation and water-management strategy. The indices calculated for the BMP sites indicate that TP loads were reduced by 4 to 40 percent. Changes in pumping volumes resulted in both increased and decreased P loading at different farms; as such, the hydraulic BMPs need to be fine-tuned. Different crops appear to be either a net sink for, or source of, P; however, water management appears to affect this observation.

Phase IV. Preliminary results of the particulate transport study indicate that the majority of particulate P discharged during pumping originates from indigenous aquatic growth. The DUFLOW modeling clearly demonstrated the potential benefits of reducing main-channel velocities and erodible mass, and illustrated that sediment traps may have only a short-term effectiveness.

Phase V . Water table depth increased from 21 inches prior to BMP implementation to 18 inches in 1996, with a concurrent reduction of P loading that is attributed, at least partly, to reduction in pumping.

Phase VI. Major reductions in TP are reported at the farm level through the implementation of BMPs (**Table 5-6**). The research results for new BMPs focusing on particulate transport and water management show the potential for greater TP loading reduction.

Phases VII and VIII. Comparison of P load to rainfall volume ratios for farms and the EAA Basin show that farm values are consistently higher, but the water year trends for each parameter appear to closely follow the District's basin figures. Farm monitoring can yield an excellent indication of what is occurring at the EAA Basin level. Specific conductance levels tend to be higher in low-lying areas across the center of the EAA. An average of about 60 percent of TP leaving farms in drainage water is attributed to particulate matter. The particulate-P found in farm drainage water is sourced primarily from floating aquatic macrophytes rather than from traditional soil erosion and bedload movement. Practices to manage floating macrophytes range from weed booms in front of structures to harvesting the plants to extract P from the water and redistribute organic matter on fields.

The influence of BMP implementation on P concentration and loading for the 10 farms was evaluated with five distinct methods that exhibited similar TP reduction trends. One of the methods employs a hydrological adjustment model developed by the District for comparison of P load between water years. The calculated UAL and adjusted UAL (AUAL) over the past five consecutive years (WY95 through WY98) are presented in **Table 5-6**.

For most of the farms, during the past four water years, AUALs were about 20 to 80 percent lower than these recorded for WY94, demonstrating that BMPs implemented are highly effective in reducing P loading at the farm level. However, reduction in P concentration is not as significant for most of the sites compared to the baseline level (**Table 5-6**). The increases in AUALs at Sites UF9204A and UF9205A reflect water management difficulties due to large-scale cropping system changes in the absence of hydraulic BMPs implemented in 1995 (**Table 5-5**). Site UF9204A has maintained its sugarcane monoculture and showed continued AUAL reduction in WY97 and WY98. Site UF9205A continues to have water management problems, with large AUAL increases in WY97 and WY98.

Summary of Farm-Scale Research

This research represents the most comprehensive, ongoing research program regarding the effectiveness of BMPs in the EAA. It is anticipated that results will be used to update the U of FL/IFAS BMP procedural guide's (Circular 1177) estimates of water management BMP P reduction potential. Comparison of P load to rainfall volume ratios for farms and the EAA Basin show that farm values are consistently higher, but the water year trends for each parameter appear to closely follow the District's basin figures. Farm monitoring can yield an excellent indication of what is occurring at the

Table 5-6. Unit area load and adjusted unit area load for WY94 through WY98 in the 10 U of FL/IFAS experimental sites.

Site	Water Year	Baseline TP (mg/L)	BMP TP (mg/L)	UAL (lbs/acre-y)	AUAL (lbs/acre-y)	% AUAL change from WY94
UF9200A	94	0.234		1.446	1.950	
	95	0.275		2.173	0.793	-50.1
	96		0.241	0.932	0.512	-73.7
	97		0.153	0.451	0.550	-71.8
	98		0.131	0.347	0.285	-85.4
UF9201A	94	0.743		3.547	6.133	
	95	0.858		5.841	3.020	-50.8
	96		0.616	2.223	1.014	-83.5
	97		0.540	0.924	0.977	-84.1
	98		0.903	10.359	10.048	63.8
UF9202A	94	0.071		0.136	0.141	
	95	0.051		0.154	0.075	-46.7
	96		0.090	0.385	0.120	-14.9
	97		0.063	0.182	0.146	3.40
	98		0.057	0.187	0.132	-6.40
UF9203A	94	0.181		0.355	0.368	
	95	0.108		0.365	0.178	-51.5
	96		0.110	0.377	0.117	-68.1
	97		0.174	0.392	0.313	-14.8
	98		0.148	0.376	0.266	-27.7
UF9204A	94	0.152		0.281	0.486	
	95	0.211		0.982	0.508	4.40
	96		0.302	1.063	0.485	-0.10
	97		0.151	0.167	0.176	-63.8
	98		0.151	0.385	0.373	-23.2
UF9205A	94	0.081		0.345	0.474	
	95	0.091		1.328	0.987	108.3
	96		0.081	1.383	0.534	12.5
	97		0.087	1.356	0.818	72.4
	98		0.069	1.483	1.576	232.4
UF9206A&B	94	0.288		2.745	3.702	
	95	0.273		3.481	1.559	-57.9
	96		0.363	2.459	1.352	-63.5
	97		0.480	4.343	5.295	-43.0
	98		0.211	2.007	1.652	-55.4
UF9207A&B	94	0.226		1.308	2.262	
	95	0.338		3.500	1.809	-20.0
	96		0.338	1.693	0.773	-65.8
	97		0.244	1.025	1.084	-52.1
	98		0.214	0.792	0.769	-66.0
UF9208A	94	0.150		0.166	0.286	
	95	0.121		0.163	0.084	-70.6
	96		0.124	0.154	0.070	-75.5
	97		0.098	0.115	0.121	-57.7
	98		0.059	0.188	0.114	-60.1
UF9209A	94	0.086		0.412	0.566	
	95	0.085		0.534	0.397	-29.9
	96		0.066	0.325	0.125	-77.8
	97		0.078	0.432	0.260	-54.0
	98		0.062	0.296	0.315	-44.4

EAA Basin level. Distributed-parameter, physics-based models such as EAAMOD and DUFLOW are cumbersome to apply at the farm-scale and may be impractical to apply basinwide due to the hydrologic complexities of the basin. However, they have contributed to an emerging understanding of dissolved- and particulate-P source, distribution and transport. This knowledge should facilitate the development of more effective on-farm sediment-management BMPs, and help to explain the cumulative effect of farm-level BMPs on P discharge from the EAA Basin.

BMP EDUCATION

With the experience and information gained from BMP implementation and research, the BMP educational program plays a key role in transferring the technology between involved parties and to the EAA growers for consideration. In 1993, the U of FL/IFAS published the first edition of the "Procedural Guide for the Development of Farm-Level BMP Plans for P Control in the EAA" (**Appendix 5: Summary Reference No. 9**). This guide was prepared to disseminate information regarding the types of agricultural BMPs that might be implemented. Prior to this period (1990-1993) an increasing percentage of landowners had implemented various BMPs because they were practical and/or for the purpose of conducting demonstrations to investigate their performance. The guide was later modified in 1995 to include information gained from the farm-scale research.

In 1993, the Sugar Cane Growers Cooperative of Florida funded a BMP training workshop for its members and other interested parties (**Appendix 5: Summary Reference No. 10**). A BMP workbook based on the first edition of the U of FL/IFAS guide was developed for the workshop. Information regarding BMP design, implementation, and project effectiveness was included. Various practices associated with each BMP were discussed with relevant case examples. The last section of the workbook contains practical questions and decision-tree matrix exercises. The workshop was beneficial to the members of the Cooperative throughout the EAA.

During 1996, the DEP funded a BMP demonstration and education program (**Appendix 5: Summary Reference No. 11**). The program was setup to assist small-acreage landowners who may not have the resources as the large growers do in terms of BMP implementation.

Throughout this same time period, the Palm Beach County Extension Service and the U of FL/IFAS Cooperative Extension Service have conducted numerous BMP workshops and seminars on various topics to transfer the technology to the growers, applicators, distributors and other EAA involved parties.

RELATIONSHIP OF BMP INITIATIVES TO TRENDS IN BASIN TOTAL PHOSPHORUS LOAD AND CONCENTRATION DATA

Collectively, the EAA landowner's implementation of BMPs through all of the BMP initiatives conducted to date has resulted in significant TP reductions from the EAA. Data collected by the District are used to characterize the load and concentration of TP attributable to the EAA and conveyed to the EPA. The basin load and concentration data measured and adjusted in compliance with Rule 40E-63, F. A. C. and the Act for all the water years of record are contained in the District's annual Everglades BMP Program reports. The complex mathematical equations, and basin tributary sources and flow patterns are described completely in the reports.

It can be difficult at times to clearly recognize any trend of P reduction from the Rule 40E-63 calculation methodology particularly with a variable calculated annual pre-BMP P level, dependent on each year's rainfall. **Figure 5-14** provides an alternative view of the EAA basin annual P values. The approach used is to combine the P load data from **Figure 5-11** with the percent reduction calculations from **Figure 5-12.** The result is a normalized view of the data to assist with the recognition of data trends to determine BMP effectiveness. The arithmetic annual average P level during the pre-BMP period is ~207 metric tons. Each annual EAA percent reduction of P was multiplied by the 207 metric ton pre-BMP annual average and plotted on **Figure 5-14** (normalized annual load = 1 –[207 mtons x annual percent reduction]). It appears that there has been a trend of P reduction occurring with the implementation of BMPs within the EAA.

The load and concentration of TP discharged from the EAA have declined in recent years compared to the 10-year pre-BMP period (Water Years 80 through 88). The Everglades BMP Program required load-reduction compliance monitoring to begin in WY96. WY96, WY97, WY98, and WY99 represent the first four years during which all lands within the EAA were required to have BMPs fully implemented. Over the last four years, cumulative P loads from the EAA have been reduced by 54 percent (preliminary WY99 data) as compared to the calculated load that would have occurred during the pre-BMP period had the last four year's rainfall occurred during the pre-BMP period (adjustment for hydrologic variability). The pre-BMP load calculations are a result of a complex regression equation developed from actual measured loads. Notable reductions in load and concentration are apparent since WY89, which is the end of the pre-BMP period used to characterize the effect of rainfall on TP loads. Monitoring records also describe an apparent trend of declining load and concentration beginning about 1992, nearly concurrently with the heightened activity regarding BMPs (**Figure 5-14**). The three-year trend lines in **Figure 5-14** facilitate describing longer-term trends and tend to smooth the year-to-year variability.

The trend of P load reduction represents a decrease of P from the combined surface water runoff attributable to the EAA farms, cities, and industry. **The calculation does not equate to a 54 percent reduction of the TP in surface water entering the WCAs from the District- operated pump stations and water control structures located at the EAA southern boundary.** The sum total of P entering the WCAs through the District-operated pumps and gates within the EAA originates from the combination of EAA surface water runoff, Lake Okeechobee environmental and urban water supply releases, C-139 Basin surface water runoff, and stormwater treatment area discharges (refer to **Chapter 4** for TP load data from the EAA to the EPA). Further, the annual flow-weighted P concentrations attributable to the EAA (total load divided by total flow) shows a similar reduction trend: **173 ppb pre-BMPs as compared to the recent three-year average 109 ppb with BMPs (Figure 5-12).**

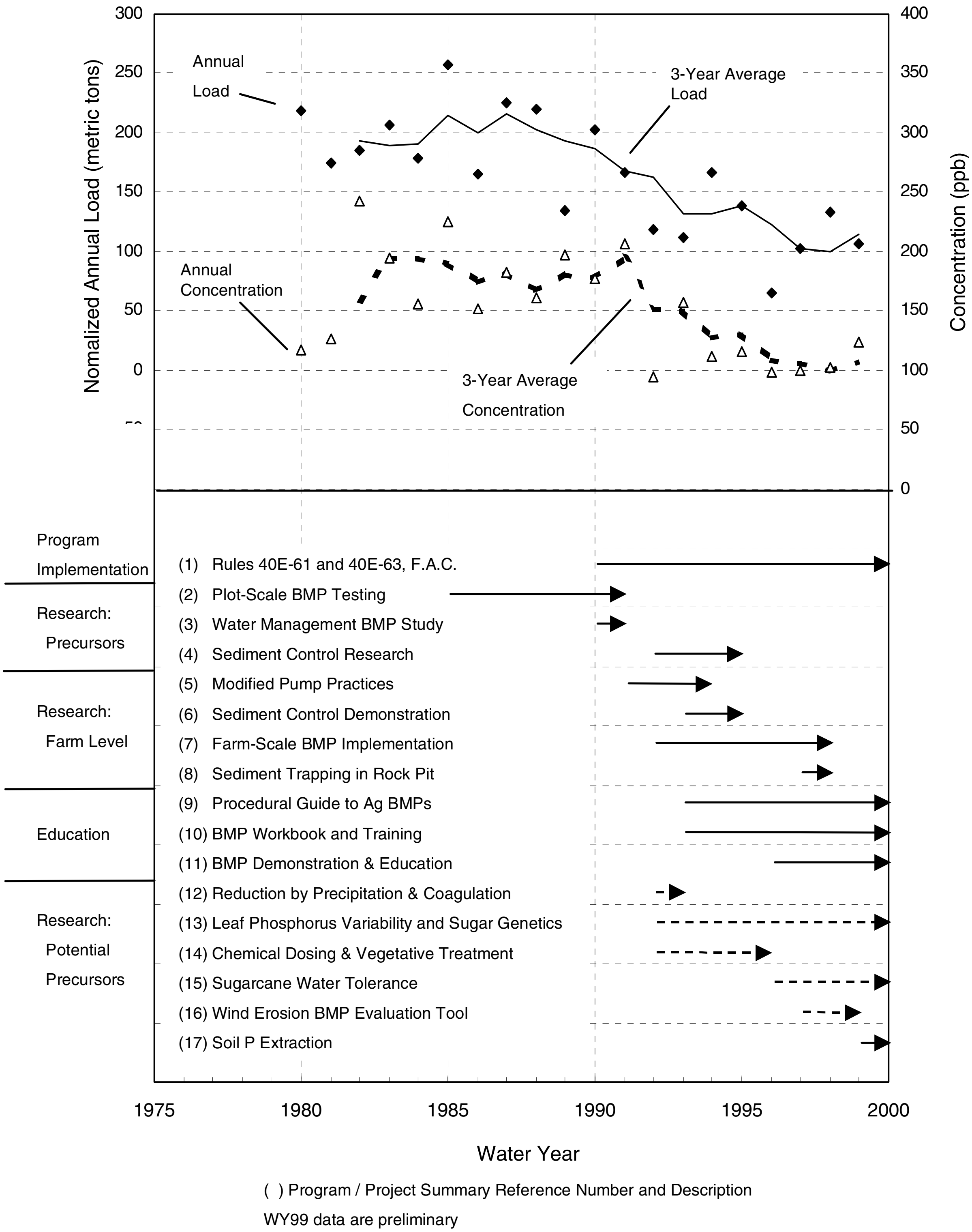

Figure 5-14. A chronology of EAA BMP initiatives and TP load and concentration.

NEW BMP RESEARCH INITIATIVES

Existing BMPs continue to be refined as experience and information is gained from prior implementation and research. For example, the District and Sugar Cane Growers Cooperative are sponsoring the U of FL/IFAS investigation of soil P extraction methods. Soil P extraction is a component of the existing Calibrated Soil Testing BMP (**Appendix 5: Summary Reference No. 7**). Therefore, further basin P reductions may be possible from the identification and implementation of additional refined BMPs. Research initiatives that may provide results to identify new BMPs are also under way and are discussed briefly below.

- The farm-scale research by the U of FL/IFAS (sponsored by the EAA-EPD) has been recently augmented to defining the particulate P transport process and particulate characteristics. Initial results indicate that a significant amount (60 percent) of P being discharged into the District's system is in the particulate form (**Appendix 5: Summary Reference No. 7**). Understanding the transport process and the source of particulate-P found in farm drainage may identify modified or new sediment control BMPs, which could result in further basin P reductions.
- The District sponsored the United States Department of Agriculture, Agricultural Research Service and Natural Resources Conservation Service to adapt the Revised Wind Erosion Equation [RWEQ97] (**Appendix 5: Summary Reference No. 16**). This recent effort developed a method that can be used to evaluate BMPs that address sediment transport by wind erosion and effectively predict loss of soils typical of the EAA. A threshold wind velocity for EAA organic muck soils was found to be approximately one half of the common threshold wind velocity for mineral soils.
- Sugarcane variety experiments. 1) Identify commercial varieties of sugarcane which utilize P more efficiently or require less P fertilization, thereby, potentially reducing the amount of P transported off site. 2) Identify commercial sugarcane varieties that are more tolerant of higher water levels thus reducing soil oxidation (a process that releases P into runoff). 3) Taking the promising sugarcane varieties from the studies identified in 1) and 2) above and genetically improving their P characteristics.

These ongoing research initiatives have potential to reveal new BMPs that could result in further basin load reductions. The U. S. Environmental Protection Agency/DEP, EAA-EPD, District, U. S. Department of Agriculture Natural Resources Conservation Service, and Agricultural Research Service, universities, and private companies are participating in these efforts.

The District is also in the process of augmenting the water quality data and limited BMP information available for the C-139 Basin. The C-139 Basin has discharged some of the highest P concentrations to the EPA and contributes the next largest P load to the EPA after the EAA. Some BMPs implemented and under investigation in the EAA may be applicable to the C-139 Basin. However, land uses and soil types of the C-139 Basin are different from those of the EAA so BMP knowledge, experience, and results may not be directly transferable. In 1999 the District initiated a C-139 inter-basin water quality monitoring network. The monitoring network will provide drainage water P levels from different areas and associated land uses within the basin. The network data will assist in selecting sites for the next BMP research phase of the project. BMP research would provide site-specific information on improving water quality. In an effort to potentially identify a C-139 Basin BMP that may also be applicable in other basins, the District is cooperating with the U of FL/IFAS on investigating silicon as a soil additive to reduce nutrient leaching in sandy soils.

The P contributions from the urban areas within the EAA have not been investigated. A significant amount of research has been conducted over the years on urban BMPs, though not specifically within the EAA Basin. The District plans to initiate cooperative BMP implementation/demonstration projects in these EAA areas, which may result in the selection and implementation of additional urban BMPs. Further improvements in water quality could also result from this work.

COSTS ASSOCIATED WITH BMP RESEARCH

Research funding has historically been contributed by at least 10 private and public entities. Currently there are six reported sources of funding for ongoing research projects. **Table 5-7** lists the total amount that each entity has contributed since 1985, based upon available information.

The various participants in the reviewed research initiatives were contacted to report the amount of funds expended. The funding listed pertains only to the BMP research cost component; it does not include the costs associated with implementation and maintenance of the practices. Refer to **Table 5-8** provided by the participating parties. The total research funding listed for all parties to date is over $10. 1 million (an approximate $1. 9 million increase over last year's Chapter 5 Everglades Interim Report total of $8. 2 million). Many of the existing research projects are anticipated to continue through 2001.

Table 5-7. Summary of contributions to BMP research.

Entity	Contribution
EAA-EPD	$5.4 Million
District	$1.8 Million
USDA Agricultural Research Service	$1.5 Million
DEP/US EPA Chapter 319	$977,000
Sugar Cane Growers Cooperative	$210,000
U of FL/IFAS	$175,000
USDA Natural Resources Conservation Service	$25,000

OTHER WATER QUALITY PARAMETERS OF CONCERN

The Act requires that the District conduct research in cooperation with the EAA landowners to identify water quality parameters that are not being significantly improved by either the STAs or BMPs, and to identify further BMP strategies needed to address these parameters. As a result of research in this area, in 1996, DEP and the District identified specific conductance, particulate P, ametryn, and atrazine as additional constituents of concern. The District amended Rules 40E-61 and 40E-63 in 1997 to define and implement a comprehensive program of research, testing and implementation of BMPs for all other water quality parameters (initially for the four previously mentioned). The research program has been incorporated into the EAA-EPD sponsored U of FL/IFAS farm-scale research. An annual review of data, including a public workshop, will occur to determine if the current research is meeting the overall objective of the Rules. If changes are deemed to be necessary, the program will be adjusted accordingly.

Table 5-8. Research initiatives and estimated amount of funds expended.

Research Initiative Period of Study Lead Researchers	**Summary No.**	**Funding Source**	**FY99 Funding (approx.)**	**Total Research Funding (approx.)**
Agricultural BMPs for P Loading in the EAA - Plot-scale 1985 – 1991 Izuno, Bottcher, and others (UF-IFAS)	2	South Florida Water Management District		$1. 52 Million
		Florida Sugar Cane League		Not Available
		Florida Fruit & Vegetable Growers Assoc.		Not Available
Water Management Study of Wetherald I and Mott No. 1 Plantations 1990 – 1991 Environmental Services & Permitting	3	United States Sugar Corporation		Not Available
Phosphorus Reduction and Sediment BMP Research 1992 – 1995 H. Andreis (United States Sugar Corporation)	4	United States Sugar Corporation		Not Available
Phosphorus Reduction and Modified Pumping Practices 1991 – 1994 Hutcheon Engineers	5	Florida Sugar Cane League		Not Available
Sediment Control Demonstration Project 1993 – 1995 Hutcheon Engineers	6	EAA-Environmental Protection District		$260,478
Implementation and Verification of BMPs for Reducing Phosphorus Loading & Other Water Quality Parameters – Farm-scale 1992 – present Izuno, Rice and others (UF-IFAS)	7	EAA-Environmental Protection District	$970,000	$5. 13 Million
		DEP/US EPA Chapter 319 (WM631)		$765,000
		South Florida Water Management District (C-E8616)		$50,000
EAA Sediments and Effectiveness of Soil Sediment Trapping in Rock Pit Diversions 1997 – 1998 Izuno & Rice (UF-IFAS)	8	DEP/US EPA Chapter 319 (WM572)		$211,635
		EAA-Environmental Protection District		$50,000
Reduction of Phosphorus Concentrations by Precipitation, Coagulation & Sedimentation 1992 Anderson & Ceric (UF-IFAS) & Hutcheon Engineers	12	Florida Sugar Cane League		Not Available
Variability of Leaf Phosphorus Among Sugarcane Genotypes (a) and Commercial Varieties (b) **(a)** 1992 – 1995 **(b)** 1994 – 1999 Glaz (USDA-ARS); Deren & Snyder (UF-IFAS)	13a&b	USDA Agricultural Research Service	$395,000	$510,000
		UF-IFAS	$100,000	$175,000
		Florida Sugar Cane League		Not Available
		Florida Crystals		Not Available
Sugarcane Genetics (c) **(c)** 1999 – present Glaz (USDA-ARS)	13c	South Florida Water Management District (C-E10663)	$70,500	$70,500
		USDA Agricultural Research Service	$75,000	$75,000
Nutrient Management System Chemical Dosing & Vegetative Treatment 1992 – 1996 Bion Technologies	14	Sugar Cane Growers Cooperative		$187,000
Researching the Water Tolerance of Sugarcane 1996 - present Glaz (USDA-ARS)	15	USDA Agricultural Research Service	$200,000	$930,000
		United States Sugar Corporation		Not Available
		Florida Sugar Cane League		Not Available
Wind Erosion BMP Evaluation Tool for the EAA 1997 – 1999 USDA Natural Resources Conservation Service	16	South Florida Water Management District (C-8511)	$8,000	$25,000
		USDA Natural Resources Conservation Service	$8,000	$25,000
Soil P Extraction/Calibrated Soil Testing BMP 1999- present Rice (UF-IFAS)	17	South Florida Water Management District (C-7641-A5)	$84,000	$84,000
		Sugar Cane Growers Cooperative	$23,000	$23,000
		TOTALS	$1. 9 Million	$10. 1 Million

CONCLUSIONS AND RECOMMENDATIONS

The goal of the BMP Regulatory Program is a 25 percent annual TP reduction from the EAA as compared to a pre-BMP implementation base period. Research data have shown that BMPs implemented reduce P export at the farm level. Landowner implementation of BMPs under the Everglades BMP Regulatory Program further demonstrates appreciable reductions in the load and concentration of TP conveyed to the EPA from the EAA Basin (54 percent cumulative reduction of P load since the required implementation of BMPs in the last four years). Further declines in P load and concentration are probable as experience and information continue to be gained from the implementation of existing BMPs and from recent research initiatives.

Because the measurements for WY99 represent only the fourth *full* water year of required BMP implementation throughout the EAA, it is still too early to predict the long-term reductions of P to the Everglades that may be the result of BMPs. As the number of annual calculations increase, staff will have increased confidence to quantify a specific level of long-term P reduction in the runoff attributable to BMPs. However, given the encouraging preliminary BMP program measurements and the performance of the initial District stormwater treatment areas (ENR Project, STA-6), **there is increased confidence that the Everglades Forever Act's interim goal of achieving 50 ppb P concentration through the combination of existing landowner BMPs and downstream stormwater treatment areas will be met.**

Since last year's Everglades Interim Report, new information has been made available. A recent research initiative on suspended particulate transport by water (**Appendix 5: Summary Reference No. 7**) indicates that an average of about 60 percent of TP leaving farms in drainage water can be attributed to particulate matter. The study reported that the particulate-P found in farm drainage water comes primarily from floating aquatic macrophytes rather than from traditional soil erosion and bed-load movement. This study suggests that practices to manage floating macrophytes such as: weed booms in front of structures, or harvesting the plants, can be used to extract P from the water and redistribute organic matter on fields. A second research project on particulate transport by wind (**Appendix 5: Summary Reference No. 16**) concluded that the threshold wind velocity for EAA organic muck soils is approximately one half of the common threshold wind velocity for mineral soils. The project also reported that keeping 30 percent of the soil surface covered with crop residue would reduce soil losses due to erosion by 70 percent. Based upon this information, wind breaks and reduced/minimum tillage may potentially reduce wind erosion and improve water quality. Two new research projects, soil P extraction investigations (**Appendix 5: Summary Reference No. 17**) and sugarcane variety P experiments (**Appendix 5: Summary Reference No. 13c**) have also been initiated.

The following recommendations are made to direct future BMP work:

- Gain an understanding of the cumulative effect of farm-level BMP plans on basinwide P discharge. Small-scale, physics-based research regarding transport is helping to explain the association but the models are complex to apply at the farm scale and may be impractical to apply basinwide.
- A relative comparison of compliance data submitted by growers regarding water and P discharges and BMPs may be useful for identifying and assisting voluntary landowners with improving their BMP plan performance. The District has initiated a work plan to investigate between farm differences.

- There is a need to further evaluate how the observed trend in basinwide P load is associated with variations in the volume of water discharged from the basin and in-source concentrations. Even though the EAA Basin recycles a significant amount of water, this may help to characterize the basinwide effectiveness of water management BMPs considered in the Everglades BMP Regulatory Program.
- Continued investigation of how antecedent rainfall conditions, timing of management practices and type of rainfall events relate to water quality could lead to additional adjustments in water management practices, though it is not clear what further reductions are attainable.
- Current agronomic tillage practices should be reviewed to determine if sustaining crop residue and maintain a higher water level are viable management practices to reduce erosion.
- P contributions from the EAA urban areas to the basin should be characterized, and appropriate BMPs demonstrated.
- The investigation of social and economic aspects of BMPs should continue with enhanced evaluation.

FINDINGS ON THE EFFECTIVENESS OF BMPS

- Initiatives between 1979 and 1999 provided information to support the EAA BMP program.
- BMP implementation has resulted in loading reductions in full compliance with the 25 percent mandated in the Act. The total cumulative load of P discharged from the EAA since the required implementation of BMPs (over the last four years) is 54 percent (WY99 data are preliminary) lower than the load that would have occurred without BMPs. The P load reduction represents a decrease of P from the EAA farms, cities and industry. The most recent three-year trend cumulative P reduction is 44 percent. The calculations do not equate to equivalent percent reductions of the TP entering the EPA from the other sources passing water through the EAA such as Lake Okeechobee releases and C-139 Basin runoff. A broader scale approach to nutrient loading can be found in **Chapter 4**.
- The documented reduction in P conveyed to the EPA from the EAA, compared to that recorded from 1979 to 1988, is attributable to landowner's implementing BMPs through the Everglades BMP Regulatory Program, as well as research and educational programs.
- Through continuing research, monitoring and refinement, further declines in P load and concentration from the EAA are probable.

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